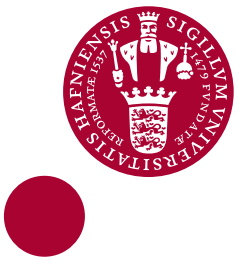

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REVIEW

Mandibular positioning techniques to improve sleep quality in patients with obstructive sleep apnea: current perspectives

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Abstract: The purpose of this article is to review 1) mandibular advancement device (MAD) – indication, treatment success, and side effects; 2) maxillomandibular advancement (MMA) surgery of the jaws – indication, treatment success, and side effects; and 3) current perspectives. Both MAD and MMA are administered to increase the upper airway volume and reduce the collapsibility of the upper airway. MAD is noninvasive and is indicated as a first-stage treatment in adult patients with mild-to-moderate obstructive sleep apnea (OSA) and in patients with severe OSA unable to adhere to continuous positive airway pressure (CPAP). MAD remains inferior to CPAP in reducing the apnea–hypopnea index (AHI) with a treatment success ranging between 24% and 72%. However, patient compliance to MAD is greater, and with regard to subjective sleepiness and health outcomes, MAD and CPAP have been found to be similarly effective. Short-term side effects of MAD are minor and often transient. Long-term side effects primarily appear as changes in the dental occlusion related to decreases in overjet and overbite. MMA is efficacious but highly invasive and indicated as a second-stage treatment in patients with moderate-to-severe OSA, with prior failure to other treatment modalities or with craniofacial abnormalities. The surgical success and cure rates are found to be 86.0% and 43.2%, respectively. Side effects may appear as postsurgical complications such as temporary facial paresthesia and compromised facial esthetics. However, most patients report satisfaction with their postsurgical appearance. Both treatment modalities require experienced clinicians and multidisciplinary approaches in order to efficaciously treat OSA patients. Some researchers do propose possible predictors of treatment success, but clear patient selection criteria and clinical predictive values for treatment success are still needed in both treatment modalities.

Keywords: sleep-disordered breathing, mandibular advancement treatment, treatment outcome

Introduction

Obstructive sleep apnea (OSA) is a multifactorial disease with age, gender, and body mass index (BMI) as predisposing factors.[1] OSA is classified as a common sleep- and breath-related disease, with an estimated prevalence of 2%–4% in the adult population.[1] The disease is chronic and progressive in nature, and the prevalence in men aged ≥60 years is as high as 30%–60%.[2] Furthermore, the disease is more common in men than in women.[2] OSA is caused by a central, sleep-induced neuromuscular hypotonia which, combined with a decreased space in the pharynx due to anatomical reasons, causes inspirational collapse of the upper airways during sleep.[1,3,4] A collapse obstructs the airways and inhibits ventilation, which results in reduction (hypopnea) or cessation (apnea) of airflow.[1,3] This obstruction of the airflow leads to continued and exacerbated

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respiratory efforts.[1,3] An apnea lasts ≥10 seconds and causes hypoxemia and hypercapnia that lead to arousals with autonomic activation and reestablishment of the ventilation.[1,4,5] Repetitive arousals cause changes in the sleep pattern with reduced rapid eye movement (REM) sleep and restorative non-REM slow-wave sleep.[4] This leads to increased morbidity and mortality in patients with OSA.[6,7]

The primary symptoms of OSA are loud snoring and excessive daytime sleepiness.[3] Furthermore, nightly choking or gasping, nocturia, morning headache, memory loss, decreased concentration, and increased irritability are also reported.[5] Studies have shown correlations among OSA and numerous cardiovascular diseases such as systemic hypertension, apoplexy, treatment refractory hypertension, and type 2 diabetes mellitus.[4,8,9] It is still questionable whether OSA is an independent risk factor for these diseases, or if the diseases occur along with the establishment of OSA, since OSA patients are often obese and show signs of the metabolic syndrome.[10] However, OSA has negative effects on the quality of life, working ability, and traffic safety along with comorbidities such as systemic hypertension threatening the patient survival.[1,3,5,6]

The diagnostic criteria of OSA are determined during a comprehensive sleep evaluation and are based on clinical signs and symptoms.[5] The patients undergo polysomnography (PSG), where the amount of apneas and hypopneas per hour (the apnea–hypopnea index [AHI]) is measured.[7] OSA in adults is classified as mild (AHI≥5 but <15), moderate (AHI≥15 but <30), or severe (AHI≥30).[6,11]

Due to the nature of OSA, the disease is often only treated symptomatically.[7,12] The primary treatment options in adults are physical and consist of continuous positive airway pressure (CPAP), mandibular advancement device (MAD) treatment, and upper airway surgery.[1,5] Failure to adhere or respond to any of the primary treatment options may indicate maxillomandibular advancement (MMA) surgery as a treatment option.[13,14] CPAP is the gold standard treatment option for OSA.[15] CPAP pneumatically splints open the airway, which is highly efficacious in preventing upper airway collapse and hence in reducing the AHI and subjective sleepiness.[15] Unfortunately, the acceptance, tolerance, and adherence to CPAP are often low among the patients, thus reducing the effectiveness of the treatment.[15]

OSA patients intolerant to CPAP treatment need to be offered other treatment options in order to reduce the increased risk of morbidity and mortality.[14,16] The overall aim of this paper is to discuss mandibular positioning techniques including MAD treatment and MMA surgery for the treatment of OSA in adults. Indication, treatment success, and side effects of MAD treatment and MMA surgery in patients with OSA are described in the following sections. Furthermore, we discuss the current perspectives of MAD treatment and MMA surgery in adult patients suffering from OSA.

MAD treatment

Indication

A MAD is a removable, intraoral dental splint used to protrude the mandible in a forward position and therefore enlarge the upper airway.[17] It represents the main non-CPAP treatment in adult OSA patients.[18] When MAD is inserted into the mouth, it works directly by enlarging the pharyngeal airway primarily in the velopharyngeal and oropharyngeal areas due to stretching of the pharyngeal soft tissues attached to the mandible.[17–19] This reduces the upper airway collapsibility by altering the upper airway morphology, structure, and function.[3,5,17] In addition, MAD treatment may influence the neuromuscular function in the upper airway.[17] Prior to MAD treatment, it is essential that the dentist performs a screening and an examination of the oral health, dental status including occlusion, and the orofacial function including the temporomandibular joints (TMDs) in order to exclude patients at high risk of unwanted side effects or patients for whom MAD treatment is contraindicated.[20] When MAD treatment is carried out by qualified and experienced dentists with regular follow-ups, MAD can be used during sleep for years, but the effectiveness is usually inferior to CPAP, and hence, MAD treatment is indicated in patients with[1,5,6,17,20]

- mild-to-moderate OSA.
- severe OSA unable to tolerate or adhere to CPAP treatment.

MAD treatment has for a long time been an alternative to CPAP treatment in mild-to-moderate OSA patients, provided that the objective treatment response of MAD treatment is sufficient.[1,5,18] However, due to similar treatment responses to MAD and CPAP treatments in the mild and moderate OSA severity, MAD may be offered as a first-line treatment in these patients.[17] Furthermore, MAD has been proven to be effective in reducing the AHI in patients with severe OSA,[21] and hence, MAD is indicated in severe OSA patients who have failed adherence to CPAP.[6,17,18]

The MAD is primarily administered to patients with 20 teeth or more, with a bone loss of <50% and evenly distributed occlusal tooth contact,[22] but the device may also be manufactured for patients with less teeth and for even edentulous patients.[23,24] The MAD should preferably be used

the whole night, at least for 4 hours each night, and at least 70% of the nights.[25] The recommended advancement of the mandible has been reported to be 50%–75% of the maximal advancement of the mandible and >6 mm, depending on the severity of OSA.[26–29]

Treatment success

The effect of MAD treatment is measured in terms of AHI reduction.[6,15] The treatment success varies due to different MAD treatment protocols and patient inclusion criteria. The treatment success is typically expressed as a ≥50% AHI reduction from baseline, resulting in a treatment outcome with an AHI of <10 events/h.[15] It is reported that the MAD treatment can reduce AHI up to 76% in patients with mild-to-moderate OSA[30] and 79% in patients with severe OSA.[30] However, in general, it is reported that the mean reduction in AHI ranges between 24% and 72% and that the mean proportion of patients who achieve a posttreatment AHI of <5 ranges between 29% and 71%.[31] However, the apnea reduction of MAD treatment may be smaller and more variable compared with CPAP treatment.[15,20] A success rate defined as a posttreatment AHI of <10 events/h has been found to range from 30% to 85% for MAD and from 62% to 100% for CPAP.[15] However, adherence to MAD has been reported to be 76%–95%, which is superior compared to CPAP adherence ranging from 30% to 80%.[30] This finding may explain why the effectiveness of MAD treatment has been found to be similar to CPAP treatment with regard to subjective sleepiness and health outcomes, such as blood pressure, microvascular reactivity, cardiac function, symptoms, quality of life, and driving performance.[6,15,17,18,20] Phillips et al, who conducted a randomized controlled trial regarding health outcomes of CPAP vs MAD treatment, also found important health outcomes (such as sleepiness, driving simulator performance, and disease-specific quality of life) to be similar after 1 month of optimal CPAP or MAD treatment in moderate-to-severe OSA patients and attributed it to the fact that MAD is superior in compliance relative to CPAP.[32] Furthermore, compared with placebo devices in patients with mild-to-moderate OSA, the MAD treatment reduces sleep apnea and subjective daytime sleepiness, and improves quality of life in OSA patients.[15,18,21,33]

Success with MAD treatment may be predicted by patient-specific factors, such as female gender, younger age, supine-dependent OSA, lower BMI, smaller neck circumference, and craniofacial factors.[17,19] A cephalometric pilot study found that retrognathia of the jaws is a positive predictive factor for MAD treatment success.[19] Furthermore, it was found that OSA patients with morphological deviations in the upper cervical spine, such as fusion of two or more cervical vertebrae, may respond poorer to MAD treatment.[19] Hoekema et al[34] investigated the predictors of treatment outcome for CPAP and MAD treatments, and found that MAD treatment was favorable in OSA patients with certain craniofacial characteristics that primarily relate to mandibular retrognathia. However, some studies have also found less effect of MAD in supine-dependent OSA[35] and inconclusive cephalometric parameters leading to their conclusion that outlying cephalometric parameters might be observed as contraindicators or "red flags" rather than predictive markers.[36] Therefore, no clinically reliable and validated method for the prediction of MAD treatment success has been established so far.[17] Further interdisciplinary research in this field is therefore necessary.

Side effects

MAD treatment is generally well tolerated by OSA patients.[17] However, short-term and long-term side effects may occur. Short-term side effects are mainly minor and transient and often end within the adaptation period which may last for a few months.[15,17,18] The short-term side effects may appear as discomfort and tenderness of the teeth, temporomandibular joint pain, myofascial pain, dryness of the mouth, excessive salivation and drooling as well as irritation of the gingiva.[3,15,17,18,37] In contrast, long-term side effects may last throughout the entire treatment and only cease with termination of the treatment.[38] Long-term side effects may appear as changes in the dental occlusion related to decreases in overjet and overbite and minor skeletal changes related to an increase in face height and downward rotation of the mandible.[15] One study on 77 OSA patients after an observation period of a decade with continued MAD treatment found long-term changes in dental occlusion to be progressive in nature.[39] They found a significant change in the relationship between the upper and lower arches where a decrease in the overbite and overjet was observed.[39] This corresponds to the findings of a randomized controlled study, where a decrease in the overbite and overjet occurred after 2 years of MAD treatment in OSA patients compared to those treated with CPAP.[37] Furthermore, they observed a decrease in occlusal contact points in the premolar region with a tendency toward a mesial occlusion (Class III occlusion) in these patients, indicating that the mandible moves toward a more anterior position.[37]

The side effects may develop due to the reciprocal forces distributed throughout the dentoalveolar and skeletal structures with the MAD in situ.[37,39] The mandibular incisors are directed labially, and the maxillary incisors are directed

palatally due to the attempt of the mandible to return to a more dorsal position.[3,37,40] Skeletal changes are undesirable and normally do not occur in adult OSA patients because the growth has ceased.[41–43] Therefore, due to the protruded jaw position, MAD treatment in OSA patients may induce changes in the dental occlusion, TMJs, masticatory muscles, and orofacial function.[3,22,39,44] However, side effects serious enough to cause patients to discontinue treatment are less likely in MAD treatment compared to CPAP therapy.[20] Furthermore, with careful control, adjustments of the MAD, and follow-ups by a dentist or dental specialist experienced in the field of orthodontics and oral physiology, side effects to MAD treatment have shown to be less harmful than previously perceived.[20,22,37]

MMA surgery

Indication

MMA surgery involves LeFort I maxillary and sagittal split mandibular osteotomies and is the most effective craniofacial surgical technique for the treatment of OSA in adults.[13,45] MMA surgery is carried out to enlarge the pharyngeal airway dimension at multiple anatomic levels, namely, the nasopharynx, oropharynx, and hypopharynx, by expanding the facial skeletal framework on which the pharyngeal soft tissues and the tongue are attached.[45–47] This reduces the inspirational collapsibility due to a physical expansion of the pharynx and the increase in tension of the pharyngeal soft tissues.[12,13,45,48] Anterior advancement of the maxilla not only expands the retropalatal airway but also may help to suspend the tongue forward due to a tension in the palatoglossal muscle.[47] Similarly, anterior advancement of the mandible directly enlarges the retrolingual airway by moving the tongue base in an anterior direction.[47] In a comparative study of OSA patients and normal controls, Butterfield et al[49] found that MMA improves the anatomy of the airways in OSA patients leading to an anatomy closer to that of the normal population. Furthermore, a review of observational studies indicates that there might be a direct relationship between the magnitude of MMA and an increased volume in the upper airway showing that MMA surgery may effectively increase the upper airway volume.[50] However, MMA has a good long-term gain in the anterior–posterior direction but limited gain in the lateral dimension of the pharyngeal airway, which is one of the limitations of MMA.[13]

The candidates for MMA surgery include adults and adolescents whose ossification of cranial structures is complete with[14,45,46]

- moderate or severe OSA (AHI>15).
- prior failure or no toleration of other therapeutic interventions, such as upper airway surgery, MAD, or CPAP.
- craniofacial abnormalities (eg, micrognathia or maxillomandibular hypoplasia).

However, it is important to determine if the patient is a candidate for other treatments, eg, lifestyle modification, weight loss, MAD for mild OSA, and bariatric surgery for extremely obese patients (BMI>35).[46,47]

Treatment success

Due to the OSA etiology as a chronic disease, the positive MMA treatment outcomes are defined as either OSA cure (AHI<5) or treatment success (AHI<20 and ≥50% reduction in AHI).[12] According to Holty and Guilleminault,[45] who performed a meta-analysis of 22 studies of MMA describing 627 adults with OSA, MMA is a highly effective and safe treatment for OSA in adults. They found the surgical success rate (AHI<20 and ≥50% reduction in AHI) to be 86.0% and the surgical cure rate (AHI<5) to be 43.2% postoperative. Another meta-analysis of MMA treatment in OSA patients also observed a reduction in AHI and an increase in the lowest oxygen saturation, indicating treatment success.[51] Most OSA patients report subjective satisfaction after MMA with improvement in OSA symptomatology (excessive daytime sleepiness, morning headache, memory loss, and impaired concentration) as well as in qualities of life measures.[45] A cohort study on the long-term effectiveness and safety of MMA for the treatment of OSA showed successful outcomes with minimal long-term treatment-related adverse outcomes.[14] They found reductions in the AHI, diastolic blood pressure, and subjective sleepiness scored in the Epworth Sleepiness Scale (ESS) along with improvements in quality-of-life measurements. The outcomes of MMA surgery appear to be equivalent to the outcomes of patients who fully adhere to and show great compliance with CPAP.[14] Therefore, they suggest that MMA surgery should be considered as an alternative treatment of choice to patients with severe OSA unable to adhere to CPAP.[14] However, few patients may experience relapse in AHI and ESS after a while.[52] Perhaps, this can be attributed to the theory that OSA is a chronic, progressive disease causing continuous stretching and destroying of the pharyngeal soft tissues resulting in relapse of apneas in some patients.[53]

Patient-specific characteristics may determine whether MMA surgery will provide the patient with a successful outcome.[13,45] The most reliable predictor of MMA surgery

outcome is preoperative OSA severity with less likelihood of achieving surgical success or surgical cure with the higher degree of OSA severity.[13] In contrast, patients with the highest preoperative OSA severity are more likely to experience greater improvement postoperatively.[13] This indicates that MMA surgery may be beneficial to OSA patients even though they have a high OSA severity. MMA surgery is not a cure for OSA but a treatment that can minimize the symptoms and multisystem damage as a result of OSA and thereby confer a mortality benefit.[13,45] Reliable predictors of MMA treatment success are as follows: younger age, lower preoperative weight, and greater maxillary advancement.[45] In contrast, no evidence of a correlation exists between the magnitude of mandibular advancement and improvement in OSA outcome,[45,54] although it is generally recommended that the magnitude of advancement of the maxillomandibular complex to treat OSA should be ~10 mm, which is well beyond the typical range to correct malocclusion or dentofacial deformities and will cause significant changes in the facial appearance and orofacial function.[47,55] Therefore, patients need to be informed about possible unwanted esthetic changes prior to MMA surgery.[47] Still, interdisciplinary research is needed for detecting a clinical, reliable, and validated method for prediction of MMA treatment success.

Side effects

MMA is a highly invasive treatment with complications such as pain, swelling, malocclusion, poor cosmetic results, facial numbness (due to preoperative pressure or damage of the inferior alveolar nerve), tingling, jaw stiffness, and postoperative relapse of advancement.[13] Complications of surgery can be divided into major and minor complications.[45] The major complication rate may be expected to be 1.0% and primarily includes incidents of cardiac arrest, dysrhythmia, and mandibular fracture.[45] However, major complications are rare and mainly associated with older age and preoperative medical comorbidity.[13] Surgical mortality is very rare and not reported in the current literature.[13,45] The minor complication rate may be expected to be 3.1% and includes mostly minor hemorrhages or infections curable with antibiotics.[45] Facial paresthesia is common (100%), but 85.8% of patients will stabilize 12 months postsurgery.[45] Furthermore, the patients may experience malocclusion postsurgery, but in most cases these changes can be resolved with regular rehabilitation therapy which is expensive for the patients and requires lifelong maintenance.[45]

Like other craniofacial surgery treatments the patients require some days of hospitalization postsurgery. A meta-analysis observed that the subjects required 3.5±3.5 days of hospitalization after MMA surgery for the treatment of OSA,[45] which is also the expected time for patients undergoing orthodontic surgery or surgery for correction of dentofacial deformities.[56,57]

The skeletal stability is crucial in the long-term treatment outcome, and it may be expected that 10%–20% surgical relapse occurs in 15% of OSA patients after MMA, but without causing any worsening of the AHI.[45] However, a clinical and cephalometric study found that advancement of the maxillomandibular complex for 10 mm remained stable,[55] which was comparable to another clinical study that also observed long-term skeletal stability after MMA surgery.[12] This might indicate that the advancement of the maxillomandibular complex should be ~10 mm to gain long-term skeletal stability along with beneficial treatment outcomes in OSA patients. Unfortunately, due to the magnitude of advancement of the maxillomandibular complex, facial esthetics and orofacial function may be compromised after surgery.[47] However, most patients report satisfaction, some patients are neutral, and few are dissatisfied with the facial esthetics after MMA surgery.[47,58] To minimize the esthetic changes, the surgeon can perform different additive corrections such as suturing the alar base which minimizes the widening of the nasal base, anterior nasal spine reduction, and genioplasty with reduction of the chin prominence.[47]

Current perspectives

MAD is accepted as an efficacious first-stage treatment in patients with mild-to-moderate OSA.[18,21] On the other hand, MMA surgery still remains a second-stage treatment available for patients with moderate-to-severe OSA even though it has been accepted as a safe and highly efficacious treatment of OSA.[14,45] Like MAD treatment, MMA surgery is not a cure of OSA, but it can minimize the symptoms and multisystem damage as a result of OSA.[13,45] Therefore, patients with residual/refractory AHI after other unsuccessful surgical procedures or treatment modalities can most often benefit from MMA.[13,14,47,58] Since CPAP therapy is still classified as the gold standard treatment of OSA, MAD and MMA surgery might be reserved for OSA patients who cannot (or will not) tolerate CPAP.[4,11] However, in terms of the present research results, it is highly relevant to discuss whether each treatment modality ought to be considered as a first-stage option taking OSA severity and compliance of the patients into consideration. MAD treatment has, as previously mentioned, a greater patient compliance than CPAP therapy and hence may be almost as beneficial in the

treatment of OSA in mild-to-moderate disease and in some cases of severe OSA. Furthermore, as CPAP therapy, MAD treatment is noninvasive and with careful patient selection and MAD treatment protocol, it has been shown to be less harmful than previously perceived.[22,37] In contrast, MMA surgery is a highly invasive treatment option and should therefore be considered carefully prior to treatment.[13,46] In the literature, it is discussed whether MMA surgery ought to be a first-stage or second-stage treatment option for OSA patients without dentofacial deformities.[12,14] Initially, MMA surgery was performed after failure of previous nasal and/or oropharyngeal surgery, but repeated research documenting beneficial treatment outcomes may underline the possibility to extend MMA surgery as a first-stage treatment for moderate-to-severe OSA patients.[12,14,58] However, it must be emphasized that there is a great intraindividual variability of AHI measurements in OSA patients causing one night PSG measurement to be less reliable for evaluating treatment success compared to measurements based on consecutive nights.[59] Most studies on MAD and MMA treatment effect rely on one-night PSG measurement pre- and posttreatment, which may cause difficulties in interpreting the actual treatment effect and hence the treatment success described in such studies.[59] However, MMA surgery is a permanent treatment option with great results in long-term stability, which might be essential in patients with generally low treatment compliance.[58] Still, continuous follow-up of MMA-treated OSA patients is necessary in order to detect a possible relapse of disease severity and to control their lifestyle.[12] Furthermore, for both treatment modalities, clear patient selection criteria and clinical predictive values for treatment success are still needed.

Conclusion

OSA cannot be cured and treatment choices such as MAD and MMA may be efficacious and beneficial alternatives to CPAP. Recent research indicates comparable treatment success of MAD and CPAP in patients with mild-to-moderate OSA as well as beneficial effects in severe cases with minimal and relatively harmless possible side effects. However, long-term MAD treatment may induce changes in the dental occlusion related to an increase in overjet and overbite. OSA patients with severe disease, craniofacial deformities, or low-treatment compliance may benefit from MMA surgery alternatively to CPAP. Current research shows great results of MMA in decreasing AHI in patients with both moderate-to-severe OSA, which may underline the possibility to extend MMA surgery as a first-stage treatment option in these cases. However, it must be emphasized that MMA is a permanent and highly invasive treatment modality with common side effects such as facial paresthesia and changes in the facial esthetics as well as risks of surgical morbidity. Either treatment modality requires experienced clinicians and multidisciplinary approaches along with regular follow-ups in order to efficaciously treat OSA patients. Some researchers do propose possible predictors of treatment success, but clear patient selection criteria and clinical predictive values for treatment success are still needed in both treatment modalities.

Disclosure

The authors report no conflicts of interest in this work.

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